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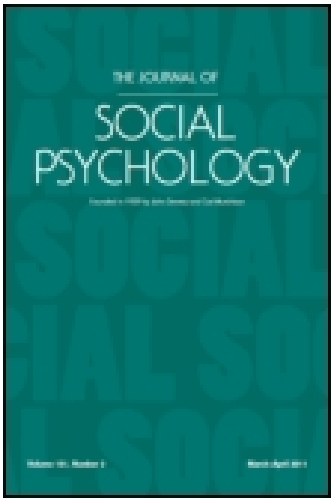


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# Experimental Results in Relation to a Mathematical Theory of Behavioral Diffusion

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# EXPERIMENTAL RESULTS IN RELATION TO A MATHEMATICAL THEORY OF BEHAVIORAL DIFFUSION*

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This paper represents an attempt to describe a theory of behavioral diffusion, on which was based a series of lectures given by the present writer at the University of Washington in the Summer of 1952, and to present two brief experiments which were undertaken as a check upon certain portions of that theory.

Diffusion theory deals mathematically with one of the basic problems of social psychology, namely, how does new behavior, once it has arisen, spread through a given population, particularly when its chief means of propagation is on a person to person basis. By new behavior we mean a response or an activity which has never appeared before and which may be expressed in any sensory modality, and which may be elicited by any type of stimulus. Such behavior may originate in one individual or, simultaneously in a group of individuals, although new behavior is *generally* assumed to arise uniquely in one individual. Such behavior spreads under various types of social constraint, such as, for example, social selectivity in acquaintanceship, and *periodic cycles of sociality* which describe the variation in any single individual's day-to-day contacts with friends, as well as dozens of similar considerations. Every psychological or sociological factor which could facilitate or impede the spread of new social behavior is quite translatable into quantitative terms, within the framework of the theory to be described. Any realistic theory of this kind, if it is to be of any genuine value, must succeed in accomplishing two basic objectives. (*a*) It must develop theoretical models which weave any number of the many types of parametric constraint which govern diffusion, into a homogeneous mathematical warp and woof, if such a theory of behavioral diffusion is to approximate the results of socio-psychological realities. (*b*) It must build models whose concepts can be operationally defined and whose parameters can be determined by ordinary statistical procedures.

The theory which we are about to present is a clock-time theory of diffusion, that is to say, a theory concerned with formulating models which will enable us to predict the growth in the spread of any kind of socio-psy-

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chological behavior. Its primary objective is to place the social psychology of imitation on a quantitative basis. Depending upon what type of behavior is being studied, the models of such a theory will incorporate psychological parameters or sociological parameters, and generally a mixture of both. Since problems of communication and the spread of information are also directly attackable by our theory, the focus of interest is not *exclusively* the social psychology of imitation. Examples of the type of behavior whose spread we would wish to study would be the passage of a new slang term through the general population, the dissemination of a rumor or of slander in a political whispering campaign, the increase in the number of people playing Canasta, the adoption of a new style of clothing, the spread of fads and hobbies, the adoption of a new feminine hair-do, and literally hundreds of other items whose enumeration need not detain us. Although we are greatly interested in the psychological factors which prompt individuals to adopt new behavior, and although we must frequently incorporate and express such factors as a parameter of some mathematical model, the main consideration will always be *the numerical growth in time of the number of individuals who exhibit the behavior we are studying.* The models of our theory are built up from certain *basic parameters,* and these will be described at this point.

The process of diffusion can be classified in three ways. These are: (*a*) atomistic diffusion, (*b*) gross diffusion, and (*c*) mixed diffusion. *Atomistic diffusion* occurs when behavior spreads strictly on a person-to-person contact basis. *Gross diffusion* is a one-way spread and occurs when behavior (or information) is spread only from a *central or gross source,* such as radio, press, pulpit, cinema, television, and other mass media of communication. *Mixed diffusion* occurs when behavior is spread in both these ways. The diffusion theory I wish to present in this paper, has models for each of these three types of *transmission process,* but the material I propose to discuss here will be limited to models of atomistic diffusion only.

As we have already remarked, any realistic theory of diffusion has to reflect many types of psychological and sociological factors, in order to do justice to the rich corpus of possibilities which can determine the spread of new behavior. However, basic to all models are four essential, statistical parameters. These are (*a*) the nature of the mode of social contact, (*b*) the nature of the repetitious contacts we make with our acquaintances, (*c*) the nature of the *acquaintance structure* which characterizes a given population, and (*d*) the *periodicity* of our social contacts. Each of these will be briefly described here.

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1. Every individual will show a variation in the number of friends, acquaintances, or associates he contacts, as time passes. By the mode of social contact we refer to any mathematical function which will express this variation, whether it be hourly during the day, or diurnally over a week. If the nature of a social group, a social situation, or a social artifact has produced some regularity in this variation and, *if in a statistical sense,* this regularity is describable mathematically, then the function which does this is said to describe the mode of social contact. Frequently social artifacts exist which make the mode of social contact rythmical with time, that is to say, it represents a repetitive pattern, and is therefore periodic. Thus for many individuals in the United States, who are churchgoers, the calendar week would be such an artifact. Sunday at church would be the week's high point of social contact, with variations to be determined from Monday through Friday, and with Saturday representing a secondary high point of social contact due to the fact that Saturday is so frequently the day for intimate social get-togethers. The reader can probably supply many other examples of *periodicity in social contact,* for himself. For our purposes, however, such periodicity may be any one of three possible types, and we therefore classify them at this point.

(*a*) *Functions with concurrent periodicity.* In these the mode of social contact is subject to some artifactual rhythm like the calendar week, and is therefore said to possess a *period, k.* During this period each individual of the population makes a variable number of social contacts in each unit of time involved. This last is, of course, meant *in a statistical sense.* In this kind of periodicity any individual's mode of social contact may be said to be at *some contact phase* of this social periodicity, for each unit of time of the period in question. When any population possesses individuals all of whom have the *identical contact phase* for every unit of time over the period, then the periodicity involved is said to be *concurrent.* To say that $n$ individuals are at the same contact phase at $t = t'$, is to say that each of them meets the same number of individuals at $t = t'$.

(*b*) *Functions with serial periodicity.* The preceding type of periodicity is a function of calendar time and is independent of the nature of the behavior which is being spread. When, however, the *contact phase* for any given individual is a function of the *psychological intensity* with which he transmits new behavior, we have a totally different situation. In these cases we are generally dealing with behavior which is of such intense interest to the diffuser that he tends to make large numbers of contacts at first with associates, in an effort to share that behavior. As interest flags, the num-

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ber of contacts declines, and eventually peters out to zero. These then are waxing and waning *intensity functions,* peculiar to each transmitter of new behavior. They are, of course, mathematically describable. As a result every convert to new behavior begins to transmit it at *Phase 1* and ends his transmission of it at *Phase k, where k is the period of the mode of social contact.* The period here is naturally the *mean length of time* which individuals in the population spend in transmitting the new behavior, and this *mean length of time* is clearly the *period of the psychological intensity function involved.* But we must clearly note here that, if $A$ and $B$ are two random individuals, and if $A$ is a converter while $B$ is not, then if $A$ meets $B$ at $t = t'$, $A$ will be at *some one of his social contact phases.* In short, the number of social contacts $A$ will make at $t = t'$ will be proportional to the value of $t'$, and the number of contacts $A$ makes over the period, $k$, will decline with the passage of time, since the mode of social contact is a function of the waning interest in spreading the new behavior. But what about $B$? If $B$ is converted at $t = t'$, then $B$ will start converting at $t = t' + 1$, but at $t = t' + 1$, $B$ will be at *Phase 1* of his social contacts, that is, at the apogee of his interest. Thus in what we have called *serial periodicity,* every converter has both a public and a private time. His public time is given by the value of $t$, his private time by the particular *contact phase* he happens to be at for each value of $t$. To put it another way, private time is psychological, being a function of the intensity of interest one has in the new behavior, and is measured by the number of contacts with our associates we are willing to make in order to share that behavior. As a result *serial periodicity* is defined as *that mode of social contact such that for any given value of public time, individual converters will show a variation in their private times.*

(*c*) *Functions with rectangular periodicity.* In these functions, *from a statistical standpoint,* every person in the population is regarded as having a mode of social contact that is *constant over time.* In short these are straight-line mathematical functions parallel to the time-axis. They are really without any periodicity, but for the sake of terminological consistency we have spoken of this mode of social contact as possessing *rectangular periodicity.*

2. The *repetitions* a transmitter makes among the acquaintances he contacts are classified as follows.

(*a*) Repetitious contact with an acquaintance that one has converted in a previous unit of time.

(*b*) Repetitious contacts with acquaintances converted by others in a previous unit of time.

(*c*) Repetitious contacts with acquaintances that one has already converted in the same time unit.

(*d*) Repetitious contacts with acquaintances that others have already converted in the same time unit.

3. The *acquaintance structure* of a population refers to the *degree of interrelatedness of its members.* It represents the measure of cohesiveness which exists among a group composed of any random individual and his acquaintances. The degree of this cohesiveness is qualitatively described as follows.

(*a*) If *i* persons are represented by a plane polygon of *i* vertices (*an iad*), and if each of these *i* persons knows all the remaining *i*-1 persons, then this can be shown by connecting every vertex to all the other vertices. This property of *mutual all-around acquaintanceship* is derivatively called *iadicity* and such a group is said to be completely *iadic.*

(*b*) If every individual possesses *D* acquaintances, and if no two of these *D* acquaintances know each other, such an *acquaintance configuration* is said to be *ramified* from the fact that if a whole population possesses this property, a diagram of the acquaintance structure will have a *branching* or *ramified appearance.*

(*c*) If some of a random individual's *D* acquaintances know each other and some do not, then the population is said to be *mixed,* that is, *partially iadic* and *partially ramified.* The degree of *internal amicability* or *iadicity, I,* can be measured for such a population by means of the formula,

$$I = \frac{D + r}{(D + 1)C_2}$$

where *r* represents all the *pairs* of one's *D* acquaintances, who know one another.

4. We have discussed *4,* in effect, under *1.*

By combining the three types of the social mode of contact with the three types of acquaintance structure, and these in turn with the presence or absence of repetition in the contacts one makes with one's acquaintances, we can develop a basic taxonomy for model building in diffusion theory. Such a taxonomy yields 18 basic structures of diffusion, each of which is modifiable for almost any psychological or sociological condition one can mention, so that any actual or assumed set of socio-psychological constraints governing the spread of some given type of behavior, can be reflected by means of some mathematical model. These 18 basic models are shown in Table 1.

In Table 1 the starred cases (10 to 18) represent our cases involving

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repetition, that is, cases in which contacts with individuals already exhibiting the spreading behavior are assumed capable of taking place. In Cases 1 to 9, it is assumed that for given, short periods of time, *for all practical purposes,* any converter who meets an acquaintance will find not only that he is not yet converted, but will also discover that he will not meet him again until after he has met all his other acquaintances *at least once.*

TABLE 1
CASES OF DIFFUSION CLASSIFIED BY PERIODICITY, GROUP STRUCTURE, AND REPETITION

| Structure | Periodicity (No repetitions) Rectangular | Serial | Concurrent |
|---|---|---|---|
| Ramified | Case 1, 10* | Case 4, 13* | Case 7, 16* |
| Iadic | Case 2, 11* | Case 5, 14* | Case 8, 17* |
| Mixed | Case 3, 12* | Case 6, 15* | Case 9, 18* |

These models are the *nuclear* models of diffusion theory. By revamping them so as to allow for various types of psychological and sociological factors and constraints, we can approximate socio-psychological realities of various degrees of complexity, and we have shown elsewhere (7) how some of the factors other than periodicity, acquaintance structure, and repetitions, must be introduced into these basic models in order to revamp them so as to approximate psychological and situational realities more closely. We will give one such example which was employed experimentally in a subsequent section of this paper. In a volume not yet published (8) all aspects of diffusion theory have been systematically explored by the present writer, far beyond the elementary exposition given in this paper,[1] with additional work along theoretical lines still in progress. The theoretical utility of both the basic models and the hundreds of revamped models is that the parameters which they require are strictly empirical, being sometimes *directly observable* and at other times calculable by statistical methods from protocol data, themselves. As hypotheses formulated to account for the spread of social behavior, diffusion models lend themselves readily to empirical verification because of the fact that we can set up the experimental conditions, ourselves, and introduce any type of constraint we wish, as has in fact been done elsewhere in the U.S.[2] Among *some of the other practical uses*

[1]The reader who is interested in the mathematical analysis of these 18 cases or in the mathematical analysis of various socio-psychological aspects of diffusion not dealt with in these 18 cases, may obtain copies of these by writing to the Washington Public Opinion Laboratory.

[2]Consult the Washington Public Opinion Laboratory under the auspices of Stuart C. Dodd, concerning the vast experimental program which has been conducted in connection with diffusion theory, under what has come to be known as "Project Revere."

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to which the models in diffusion theory can be or have been put, are the following: (*a*) application to the problem of assessing how far and how rapidly propaganda may be disseminated among populations of a particular description, a matter which has been of interest to certain government agencies; (*b*) an organization and classification of the factors underlying communication, rumor, and the spread of information; (*c*) applications in the study of the genesis and growth of consumer preferences in relation to market research techniques, and (*d*) the development of a mathematical social psychology of acculturation. There are additional practical and theoretical uses for diffusion theory, but these cannot be entered into in this paper. At this point, however, I should like to turn to a discussion of model construction and experimental techniques for their verification. I shall introduce three models, Cases 10 and 11 of Table 1, together with a revamping of Model 11. Model 10 will be presented for expository purposes only, without any consideration of experimental work. Model 11 as well as its modification, will both be presented as hypotheses to account for the spread of new social behavior *in two different experimental situations.* The observational data from these experiments will be furnished together with the data calculated theoretically from the models, and a brief statistical analysis will be furnished of the goodness of fit of the predicted to the observed data.

We shall first present Case 10 without comment. The model for Case 10 represents a hypothetical situation in which a population's acquaintance structure is *completely ramified,* in which the periodicity of the mode of social contact is *rectangular,* and in which any converter is assumed capable of meeting his acquaintances more than once.[3] Let the mode of social contact be represented by the function, $\phi(t) = m$, that is, every person contacts *m different persons* per unit time, and let $D$ equal the size of any person's circle of acquaintances. When any recent convert starts his own conversion cycle, he has a certain probability of meeting his own converter. This is given by 1/D. Now let the symbol $\triangle_t$, represent the *increment of converts* made by any transmitter, at *t.* Then

[3]Underground political or revolutionary movements which form cells with cell leaders and cell rank and file, in which no two of the cell rank and file know each other, altho each rank and file member is a leader in another cell, satisfy the conditions of Model 10. This is particularly true when each cell leader meets his followers at stated periods, and every follower meets his own cell rank and file at subsequent periods; and every cell leader requires several meetings in order to pass on information which is to be spread, because not all his followers show up at any one meeting and several show up at more than one meeting. This type of political structure is aimed at minimizing the number of people who can be rounded up when one or more members of this party population is apprehended by the authorities.

$$\triangle_1 = m - m/D = m(D - 1)/D = mC \qquad (1)$$

We also have that

$$\begin{aligned} \triangle_2 &= m - m(\triangle_1 + 1)/D \\ &= m - m\,[m(D - 1)/D + 1]/D \\ &= m[(D - 1)/D]\;[(D - m)/D] \\ &= mCK^{2-1} \end{aligned} \qquad (2)$$

where $K = (D - m)/D$ in equations (2), and in general we shall find that for any transmitter who is passing on the new behavior *at the t-th unit of his own conversion cycle,* we have that

$$\triangle_t = mCK^{t-1} \qquad (3)$$

where K = (D—m)/D.

The preceding equations merely show us what happens during any random transmitter's own conversion cycle. It represents the increments in the converts to the new behavior, which are produced at each different time unit of that conversion cycle. However, all converts are adding increments in each unit of time and, in general, at any one value of *t* different converts are transmitting the new behavior at *different phases* of their respective conversion cycles. In other words, even though Case 10 involves *rectangular periodicity,* since the mode of social contact is both constant for each person and the same for all persons, nevertheless it represents a case of *cryptic serial periodicity*. This is so for two reasons. First, each transmitter, under the conditions of Case 10, *meets a variable number of different, new, non-converts among his acquaintances, from day to day, so that his effective periodicity is serial.* Second, during the conversion process, *every converter has his own private time which cuts across the public time.* We therefore have to turn to the task of obtaining the *total increment of new converts* to the spreading behavior, *which is produced by all the converters acting at any given time,* not merely any single converter. In order to do this, we have to introduce the notion of a *P*-schema or increment schema. An increment schema will be a notational device or tableau for showing what the *total increments* will be for each value of *t*. In order to simplify our explanation of what we mean by a *P*-schema, we shall let $\triangle'_t$ represent the *total increment* at time, *t,* and we shall make the following substitution,

$$\triangle_t \equiv P_t \qquad (4)$$

Then in a population possessing *ramified* structure, and subject to the conditions of Case 10, every individual transmitter will generate the parti-

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cle, $P_i$, at $t = i$, *in his own private time.* All members of every newly generated particle, such as $P_i$, will, in turn, generate a series of particles, *starting in public time,* the first of which will be $P_1$, the second, $P_2$, etc. In order, however, to see the relation between the increments in private time produced by any single transmitter and the total increments which occur in public time, we must set forth below the *tableau* to which we have already made reference. If we let $P_0 = 1$ represent the starter or the primary distributor of the new behavior, and $\triangle'_t$ the total increment at public time, *t,* we will obtain the following schema:

$$\begin{aligned}
\triangle'_0 &= P_0 \\
\triangle'_1 &= P_1 \\
\triangle'_2 &= P_2 + P_1^2 \\
\triangle'_3 &= P_3 + 2\,P_1P_2 + P_1^3 \\
\triangle'_4 &= P_4 + 2\,P_1P_3 + P_2^2 + 3\,P_1^2P_2 + P_1^4 \\
&\cdot \\
&\cdot \\
&\cdot \\
\triangle'_t &= F(h_t, P)
\end{aligned} \tag{5}$$

The notation, $F(h_t, P)$ is to be read as "the function in $P$ the aggregated subscripts of whose terms represent each of the *partitions* of the integer, *t,* and the coefficients of whose terms are the permutations of each such partition."

Now in order to obtain the *total increments* for Case 10 we have to make the appropriate substitution of $P_1$ in the increment schema, represented by equations (5).

Since we now have that

$$\triangle_1 \equiv P_1 = mCK^{i-1}, \tag{6}$$

if we make the substitutions mentioned above, we obtain

$$\begin{aligned}
\triangle'_0 &= 1 \\
\triangle'_1 &= mC(K + mC)^0 \\
\triangle'_2 &= mC(K + mC)^1 \\
\triangle'_3 &= mC(K + mC)^2 \\
&\cdot \\
&\cdot \\
&\cdot \\
\triangle'_t &= mC(K + mC)^{t-1}
\end{aligned} \tag{7}$$

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Since it can be shown by a proof we shall not furnish here, that the dropping of $C$ within any of the expressions of equations (7), is absolutely negligible, we will then have that

$$\triangle'_t = m(K + m)^{t-1} \qquad (8)$$

and since $K = (D—m)/D$, substituting in equation (8) we obtain

$$\triangle'_t = m\{[D(m + 1)—m]/D\}^{t-1} = mR^{t-1} \qquad (9)$$

We now have the problem of determining the *accumulated total increments* over the total interval of time during which conversion has been taking place throughout the population. This is an interval consisting of $t$ units of time. If we let $N(t)$ represent the *sum* of all the separate total increments over this period, we have that

$$N(t) = m + mR + mR^2 + \ldots + mR^{t-1} + 1 \qquad (10)$$

and since equation (10) represents an ordinary power series we get

$$N(t) = m\left(\frac{R^t - 1}{R - 1}\right) + 1 \qquad (11)$$

Expressing equation (11) in terms of $m$ and $D$ only, by substituting $R = [D(m + 1) — m]/D$ into equation (11), yields

$$N(t) = \frac{[D(m + 1) — m]^t — D^t}{D^{t-1}(D — 1)} + 1 \qquad (12)$$

Here $N(t)$ of equation (12) gives us the *total number of individuals* who will exhibit the spreading new behavior, after a lapse of $t$ units of time.

In Case 11 to which we will now address ourselves, we have the following conditions. We have a population whose acquaintance structure is completely iadic, that is, *everyone has the possibility of contacting and converting anyone else.* Thus this population is completely iadic *with respect to the behavior in question.* This does not necessarily mean that everyone knows everyone else, though it *may* mean that for some populations. The mode of social contact is assumed constant for all, that is, everyone meets the same number of persons per unit time, or, in short, we have rectangular periodicity. Finally every converter may make repetitious contacts with individuals who are already converted.

In Case 11, if the total population is $M$, and if the number of *infected or converted* individuals at the start of any given time, $t$, is $N(t — 1)$, then the probability that any random converter will not have a repetitious contact is $[M — N(t)]/M$. If we let $K = m/M$, then the following recursion equation will give us $N(t)$.

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$$N(t) = N(1)\,[N(t-1)] - K\,[N(t-1)]^2 \qquad (13)$$

Methods have been devised for expanding equation (13) and evaluating each term of the expansion, since every term of the expansion is of the form

$$nK^r(1-K)^{r+1}\,N(1)^x$$

and the total value of the expansion for any value of $t$ can be determined by rather simple, algebraic methods. This being so we should like to describe below a simple experiment which was conducted under the auspices of the University of Washington in order to check the power of Model 11.

The following diffusion experiment was conducted at a Y.M.C.A. summer camp in July, 1952. During a two-hour rest period a population of 37 out of 42 boys were involved in the acquisition of new behavior which consisted of acquiring and wearing a certain type of pin. The group was small, all knew each other, and therefore the population in question was completely iadic. The distance factor between interactors was negligible and other conditions were kept fairly constant. The experimental time interval involved was a two-hour period. The observations required were made in 15-minute intervals of this two-hour period. There were no other competing activities during the experimental interval and the act of acquiring the pin was unrepeatable. The number of starters or primary distributors here consisted of three boys, one a leader, one an isolate, and one a "middler," as determined from a previously administered sociometric test. The growth in the number of boys who acquired the pin was recorded, as already remarked, in 15-minute intervals. The experiment was conducted as follows.

The three "starters" were given a large yellow pin with the name of the camp and a question mark in black on it. Each was told:

> Here is a special pin. It is important that you wear it today. We have a few more of them, but not enough for all the campers. Those campers who find out about this and come to the "Old Lodge" will also get a pin, as long as our supply lasts. Remember, it is important that you wear it today, and remember that we don't have very many pins.

As each of the starters went back into the camp, others saw the pin, asked about it and came to get one like it, and presumably non-converts who were seen by new converts were affected by these latter in the same way that non-converts would be affected by the starters. Here $M = 42$ and, although $m$ was not directly observed at the time of the experiment, since Model 11 had not yet been developed, a guessed estimate of $m$ was made. We must

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remind the reader here that $m$ is the mode of social contact, that is, the *average number of persons* each of the boys contacted per unit time of 15 minutes. The value guessed for $m$ at the time was 1.0, later actually found to be very close to the true value of .92. In Table 2 the observed number of converts during the experimental 15-minute intervals and the predicted number of converts, based upon the recursion relationship of equation (13), have been set forth.[4]

TABLE 2
GROWTH OF THE PIN-REQUESTING BEHAVIOR AT A CAMP (A TEST OF A DIFFUSION MODEL)

| Clock time interval $t$ | Expected converts $e$ | Observed converts $o$ |
|---|---|---|
| 12:45 | 3.00 | 3 |
| 12:46 to 1:00 | 2.76 | 0 |
| 1:01 to 1:15 | 4.84 | 6 |
| 1:16 to 1:30 | 7.74 | 9 |
| 1:31 to 1:45 | 9.17 | 8 |
| 1:46 to 2:00 | 7.15 | 5 |
| 2:01 to 2:15 | 2.08 | 3 |
| 2:16 to 2:30 | 0.37 | 2 |
| 2:31 to 2:45 | —— | 1 |
| Total | 37.11 | 37 |

As the reader can see, the expected and observed number of converts in each 15-minute interval, agree fairly well. The Washington Public Opinion Laboratory worked out a closeness of fit correlation coefficient and obtained $r_{eo} = .85$. This was acceptable at the 5 per cent confidence level, although it was not up to the standard generally sought by the *WPOL*, namely, a value such that $r_{eo} > .9$. However, the *WPOL* concluded that an $r_{eo}$ of .85 on uncumulated data was a sufficiently fair fit of the expected values of Model 11 to the observed data, to warrant further experimentation which was subsequently undertaken.

I now wish to describe a second experiment which was undertaken by the *WPOL*. This experiment is known as the Chain Tags experiment, and was repeated in each of four matched villages of about a thousand population each. In order to induce individuals to pass on a printed message from person to person (atomistic diffusion), a modification of the chain

[4] I am indebted to Professor Stuart Carter Dodd and his associates for the details of the experiment described above, for the computation of the theoretical frequencies, the construction of the table, and for the statistical analysis, findings, and interpretations. I am also indebted to the same source for the analogous considerations applying to the second experiment to check a theoretical model, an account of which is also given in this paper.

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letter idea was employed. Ten representative starters were chosen for each of these four communities. Each of these 10 starters was given a cellophane wrapped packet containing an identical batch of postcards with a return address. Each packet could be broken up by every recipient of it, into a "tracer" postcard to be filled out and mailed in and a subpacket which was to be given to someone else. Each primary packet containing a series of 10 subpackets, allowing it to pass through a chain of 10 persons through not more than 10 removes. Each card provided for the name and address of the receiver and provided space for him to supply the name of the person who gave him the packet, the name of the person to whom he gave the packet, and the time and place at which both these transactions took place. A different type of motivation was employed in the conduct of this experiment, in each of the four towns. In Town 1 it was "to help science," in Town 2 "to help Civil Defense," in Town 3 "to help a modern Paul Revere in an emergency" (that is, to test whether a vital message could be spread in this person-to-person fashion), and in Town 4 the motivation was "to earn a dollar" (a payment for responding). Three weeks were allowed for the process of diffusion to run its course, this being the deadline date printed on the cards. Measures were taken to eliminate the effects of daily and other cyclic activities. Distance may have had some effect, though that effect was believed to be minimal, and insufficient data were present to determine the effect of distance. The stimulus, motivation, and other conditions appeared to be fairly constant within each town. Here the number of *primary distributors* (starters), the mode of social contact (number of persons contacted by a packet-mailer per unit time), the total population ($M$), and the total period or interval of diffusion ($t$) were all experimentally controlled in this Chain Tags experiment.

By virtue of the conditions described above, the appropriate theoretical model required, was a variant of Model 11. In this experiment, *only* what we have previously called $\Delta'_t$ namely, the *total increment* or *growth of converts* at time *t, can continue the conversion process.* All converts from $t = 1$ to $t - 1$, *drop out of the conversion process,* since, so to speak, they have "but one packet to give for their country." The only effective transmitters are the *current holders of a subpacket.* As a consequence a modification of Model 11 was developed, with whose formulation we will not burden the reader here, in order to take care of the necessary relevant conditions described in the foregoing. The *modified* model was then applied to the data from the four towns combined. The number of receivers predicted from the modified model and the number of receivers actually observed

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were then compared, in terms, however, of the removes or the number of persons receiving packets per each ordinal link of the transmission process, itself. This method of recording dispenses with the use of chronological units. As we have already remarked, there can be, at most, 10 such removes. The expected and observed frequencies are set forth in Table 3.

TABLE 3
GROWTH OF THE MESSAGE-RECEIVING BEHAVIOR IN FOUR TOWNS

| Order of the remove | Expected receivers | Observed receivers |
|---|---|---|
| zero-th | 40.00 | 40 |
| 1st | 28.00 | 28 |
| 2nd | 23.00 | 23 |
| 3rd | 21.19 | 23 |
| 4th | 24.97 | 20 |
| 5th | 18.88 | 19 |
| 6th | 19.38 | 16 |
| 7th | 14.56 | 10 |
| 8th | 7.12 | 7 |
| 9th | 5.36 | 7 |
| 10th | 6.97 | 8 |
| Total | 209. | 201 |

The closeness of fit correlation for the uncumulated data, worked out by the *WPOL,* was .93, with a goodness of fit from sampling acceptable at the 1 per cent confidence level. The *WPOL* noted that this $r_{vo}$ of .93 exceeded its standard of .9 and the 5 per cent confidence level, and concluded that the variant of Model 11, adopted for this experiment, fitted the data well and that, under like conditions of random and steady state diffusing, it may be expected to predict well in new diffusion situations.

Diffusion theory is still in its infancy. The examples I have given here of my own theoretical approach, is but an extremely small sample of the theoretical area covered, and my own approach is but one of many which are being tried throughout the country. This paper is written to kindle an interest in this little known sector of psychology, while at the same time reemphasizing the importance and the use of mathematical methods in the behavioral sciences, a matter to which others have recently called attention (3, 5, 6). The area of the social flow of behavior is vast enough to be studied by many approaches, and behavioral diffusion is but one type of flow system. Analysis of other types of social flow systems has begun in other quarters (1, 4). The quantitative rationales in psychology and the behavioral sciences should be accepted in the spirit in which Hull (2) spoke of these in the epilogue to his *Principles of Behavior.* Perhaps progress in

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psychology may be accelerated somewhat, if the empirical aspects of the nomothetic approach are aided and abetted by an increasing use of mathematical techniques.

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